Proc. NIPR Symp. Polar Biol., 5, 21–27, 1992

USAGE OF SEAWATER SYSTEM FOR LONG-TERM STUDY OF PHYTOPLANKTON IN THE BOREAL COASTAL WATER OF HOKKAIDO, JAPAN

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Abstract: Weekly sampling was begun in October 1989 for 13 months to monitor the seasonal change of environmental characteristics and biological events in the boreal coastal water of Hokkaido, Japan. Water sample was taken from a seawater system for aquaculture studies. Concentration of chlorophyll *a* indicated clearly a seasonality. The low concentration was observed in winter, and spring bloom peaked on March 5 and lasted for eight weeks. The termination of productive season was a result of the change of water mass which occurred in May and June. During summer the concentration was lower than $1.0\,\mathrm{mg\cdot m^{-3}}$. No fall bloom was observed. The present monitoring program using the existing seawater system will help to identify the succession of water mass, the seasonal change of chemical environments, and the timing and duration of spring bloom, which may be the important factor for maintenance of the coastal ecosystem including larval fish production.

1. Introduction

The boreal coastal water is a spawning area for commercially important fish such as Pacific herring (*Clupea pallasi*), Japanese sandfish (*Arctoscopus japonicus*), and Shishamo smelt (*Spirinchus lanceolatus*). They lay eggs on macroalgae and other objects (IIZUKA, 1966; KITAHAMA, 1968; OKADA *et al*., 1975). When they hatch in this shallow water, survival rate of newly hatched larvae may depend on food availability rather than mortality due to grazing. Match or mismatch with food may be critical to further fish yield (CUSHING, 1981). A spawning period ranges from November for Japanese sandfish to May/June for Pacific herring in the boreal coastal water of eastern Hokkaido. Most eggs hatch within a few months. The newly hatched larvae during the spring bloom are more likely dependent on the food produced during the productive season than other fish larvae hatched in different seasons. However, their survival is still affected by the timing, duration, and amplitude of spring bloom. The present study aims to identify the timing, duration, and amplitude of spring bloom in relation to larval fish production based on a weekly sampling program using the existing seawater system.

2. Materials and Methods

Seawater samples were collected weekly with acid-cleaned 2-liter dark bottle

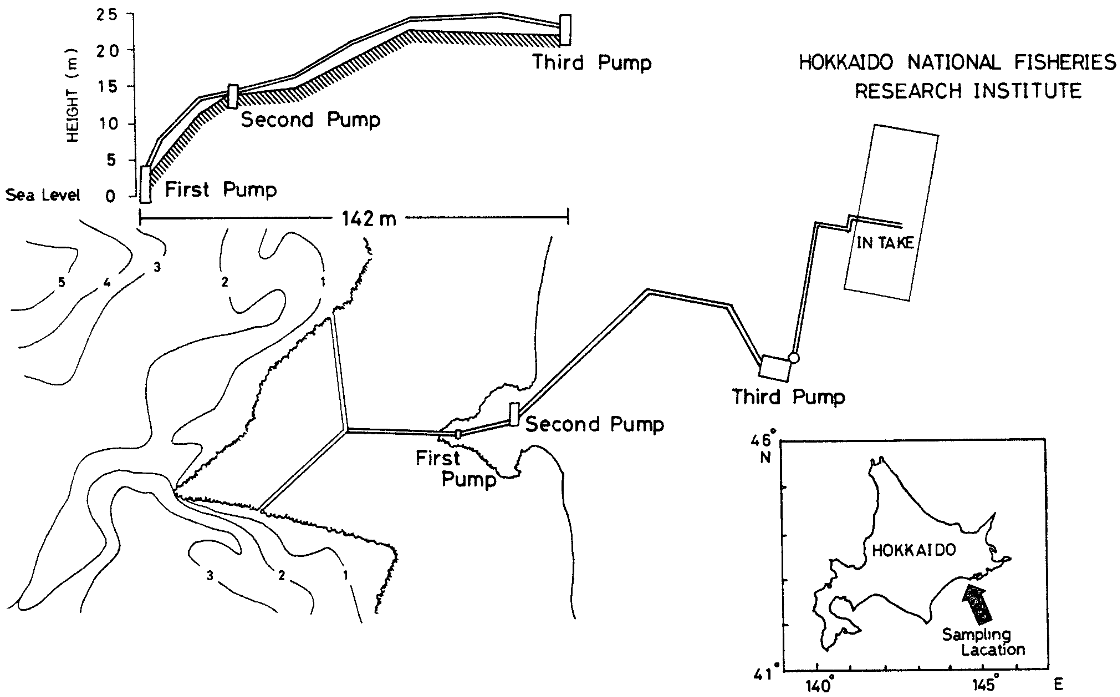

Fig. 1. Seawater system at the Hokkaido National Fisheries Research Institute, Kushiro, Hokkaido, Japan. Numbers along the contour lines indicate the depth of bottom. The top left portion indicates a vertical height of three pump stations in relation to the sea level. The total length from the first to third pump stations was 142 m. Inserted map indicates a sampling location.

from the seawater system at the Hokkaido National Fisheries Research Institute (Fig. 1). The seawater system had separate lines for untreated and treated seawater, respectively. The untreated seawater was pumped continuously to the aquaculture facility although the treated seawater had some residence time in a stored tank at the third pump station. The flow rate of this untreated seawater was about 10 liters per minute. Samples were prescreened through a 183 μm screen to remove large particles. At first the temperature was determined by a thermometer with an accuracy of 0.1°C and subsamples were taken for salinity determination. Subsamples of 100 ml were filtered onto glass fiber filter type GF/F for determination of concentrations of chlorophyll *a* and pheopigments. The filter sample was placed on the bottom of a plastic vial with a few ml of 100% acetone. The filtrate was collected for analysis of dissolved nutrients.

Salinity was determined on the Environmental Electronics salinometer model 601 MklV. The concentration of chlorophyll *a* and pheopigments was determined on the Turner Design fluorometer model 1000 with a method of HOLM-HANSEN *et al.* (1965). Nitrate, nitrite, silicate and phosphate were determined on the Auto-Analyzer model Traacs 800 with a method of BRAN and LUBBE (1989).

3. Results and Discussion

Seawater temperature reached 19°C in August while the minimum temperature of

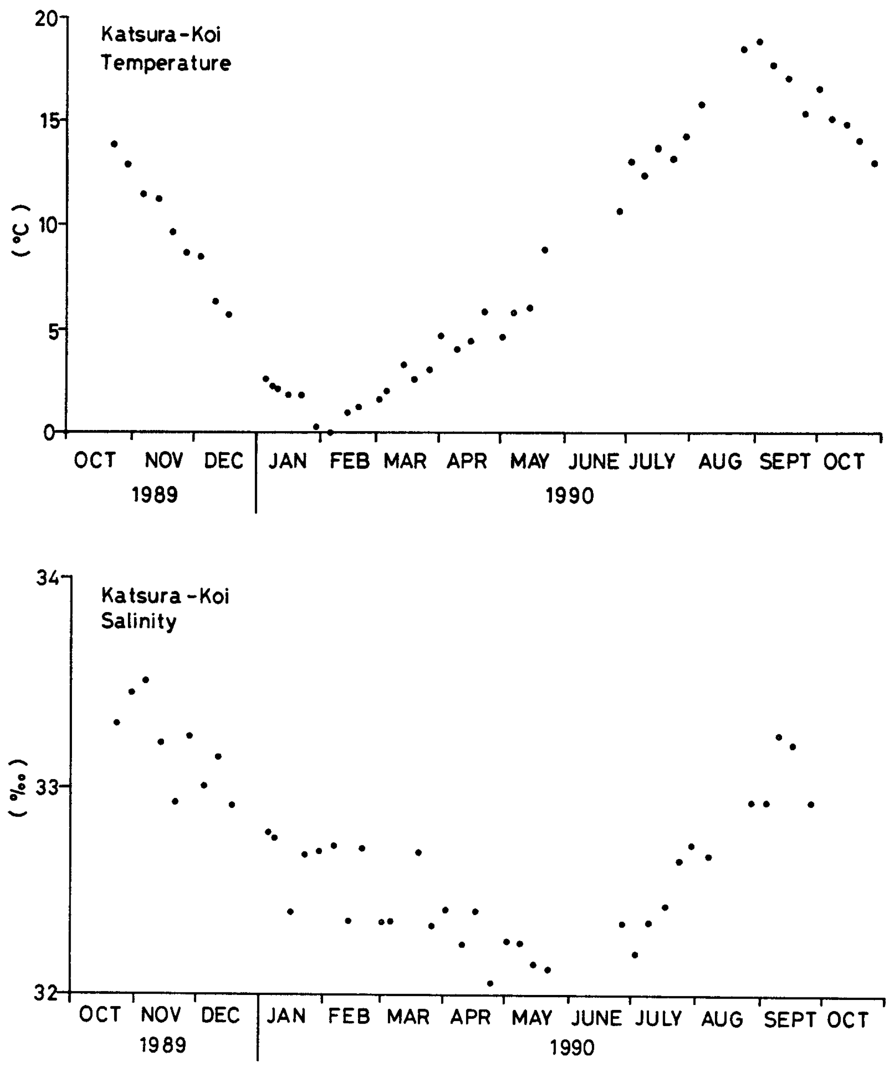

Fig. 2. Seasonal changes of seawater temperature (°C) and salinity (ppt) observed from weekly collected water samples at the Hokkaido National Fisheries Research Institute during the period from October 1989 to October 1990.

0°C was observed in February (Fig. 2). The seawater temperature rose at a rate of 0.070°C·day^{-1} until June and then continued to rise at a faster rate of 0.125°C·day^{-1} than the first half of warming period. Salinity decreased to the minimum of ca. 32.2 ppt in May and June and increased to the maximum of 33.5 ppt in November. The inflection point of temperature curve during the warming period coincided with the occurrence of the salinity minimum in May and June. This suggests clearly a water succession which is characterized with a dominant occurrence of the Okhotsk [Oyashio] cold coastal water with low concentration of nitrite in May and June and the Soya warm coastal water with high concentration of nitrite in fall, respectively (Fig. 3). A Si/P ratio during the first half and the second half of warming period was 18±3 and 21±4 (95% confidence limits), respectively, compared with 25±4 for the cooling period from October to January. A similar seasonal observation was made at 10–50 km offshore from the present site by TANAKA *et al.* (1991).

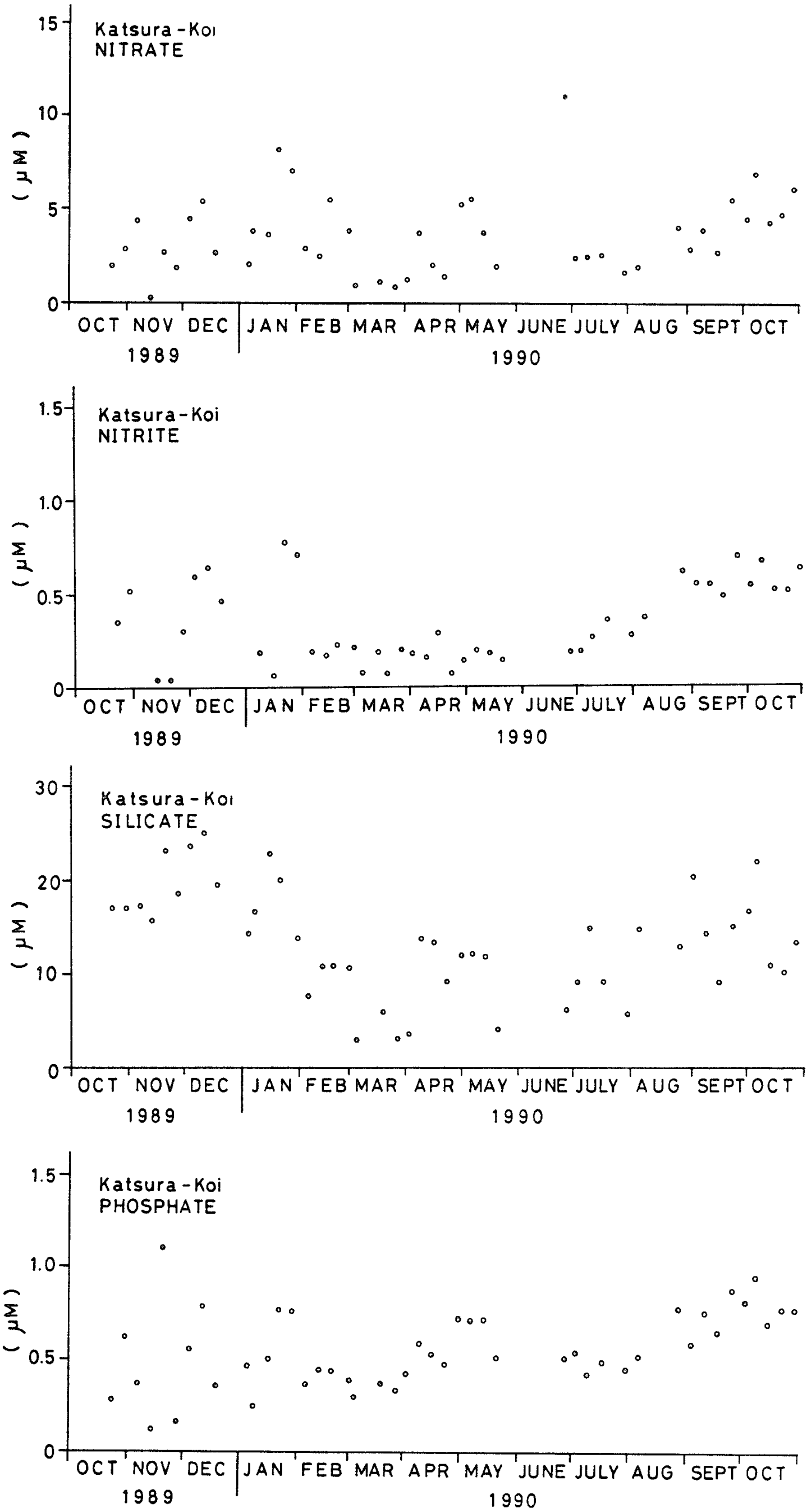

Fig. 3. Seasonal changes of nitrate, nitrite, silicate, and phosphate (μM) observed from weekly collected water samples at the Hokkaido National Fisheries Research Institute during the period from October 1989 to October 1990.

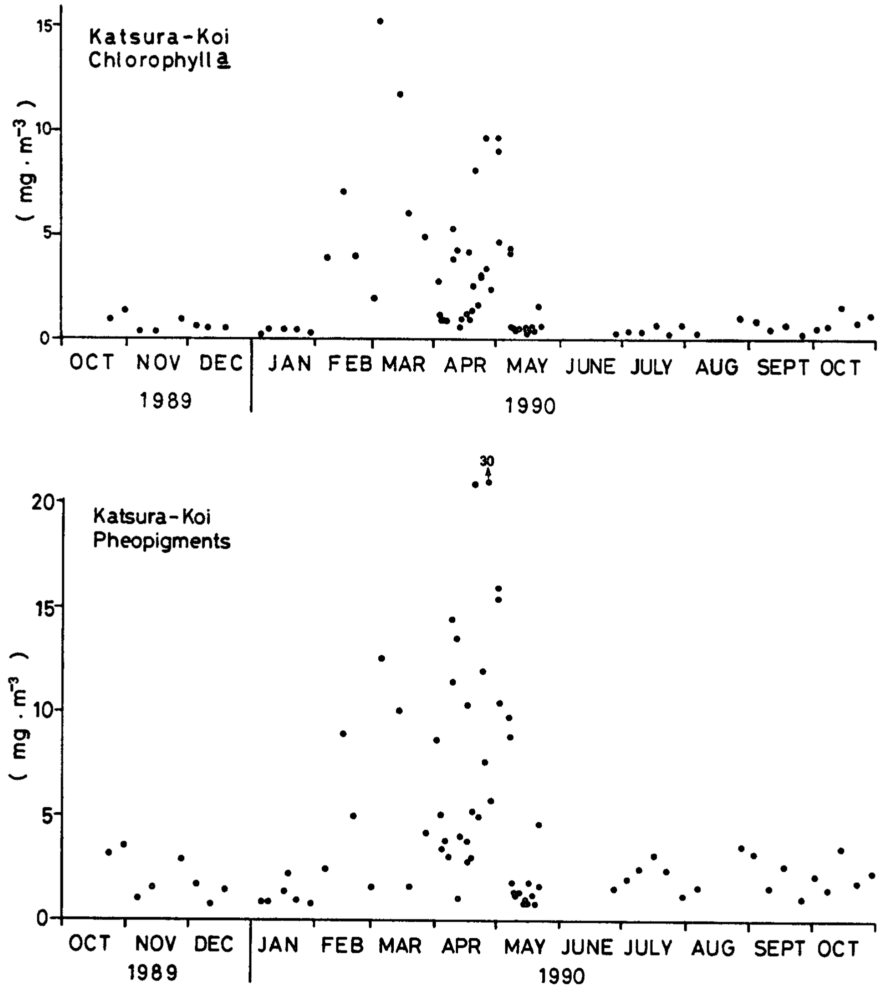

Fig. 4. Seasonal changes of chlorophyll a *and pheopigments* ($mg \cdot m^{-3}$) *observed from weekly collected water samples at the Hokkaido National Fisheries Research Institute during the period from October 1989 to October 1990.*

Spring bloom of phytoplankton started in the first week of February when seawater temperature began to rise. The peak concentration of chlorophyll *a* was 15 $mg \cdot m^{-3}$ (Fig. 4). A relatively high concentration of chlorophyll *a* was maintained during the first half of warming period. The chlorophyll *a* concentration sharply dropped to less than 1 $mg \cdot m^{-3}$ during the second half of warming period. Degradation products of chlorophyll *a*, *i.e.* pheopigments, showed a similar seasonal change to that of chlorophyll *a* with a two-month delayed peak at the end of April. This phased occurrence of pheopigments with relatively high concentrations suggests a strong evidence of grazing pressure on phytoplankton (WELCHMEYER and LORENZEN, 1985). This grazing pressure can be provided either by zooplankton or by fish larvae. However, no direct relationship between the pheopigment increase and the occurrence of zooplankton or newly hatched fish larvae can be determined in this study due to a lack of relevant study.

CUSHING (1981) proposed a "match or mismatch theory" to explain a natural fluctuation of fish yield. The present study indicated a four-month productive season in the boreal coastal water of Hokkaido. Prior to this period the following fish start laying eggs although some fish continue to lay eggs even during the productive season (MATSUOKA, 1975). They usually hatch within a few months to take advantage of abundant food. However, larval stage of some fish such as walleye pollock *Theragra chalcogramma* may have a high risk to survive since they lay eggs during the period from November to January along the coast of Hokkaido. When the spring bloom is delayed one month or so, the newly hatched larvae may have less food for surviving for some time. Compared to walleye pollock, thornyhead *Sebastolobus macrochir* may be well adapted to temporally variable environments. They lay eggs during the period from January to June so that some population of these larvae is always guaranteed to encounter abundant food for surviving. However, fish larvae may still reveal a fluctuation of their abundance depending on the size of spring bloom (HALDORSON *et al.*, 1989). Eventually this fluctuation in the abundance of larvae may be related to a fluctuation of their yield. A long-term comparison of fish yield with timing, duration, and amplitude of spring bloom would be necessary to test this hypothesis in future.

4. Summary

1. A seawater system for aquaculture research can be very useful to follow a seasonal change of environmental characteristics and biological events.

2. Weekly sampling is short enough to identify the amplitude of seasonal changes observed in the environmental characteristics and biological events in the coastal area.

3. Seasonal changes of chlorophyll *a* and pheopigments are strongly controlled by the succession of water mass along the coast of Hokkaido, Japan.

4. The present kind of monitoring program may be useful to predict a possible fish yield in the following year.

Acknowledgments

I greatly appreciate T. KONUKI for her technical help. Salinity analysis was made by M. ISHIDA. H. SAITO is greatly appreciated for his nutrient analysis. Turner Design fluorometer was kindly loaned for chlorophyll analysis by K. KURODA. Special thanks are extended to A. IWAKUMA and Y. KOBAYASHI, who kindly provided a detailed structual information of the seawater system. All drawings were made by N. KUDO. Discussion with T. MINAMI improved the earlier version of manuscript. I am grateful for the contribution of B517 from the Hokkaido National Fisheries Research Institute.

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(Received April 15, 1991; Revised manuscript received August 12, 1991)